FORM PTO-1390 (Modified) (REV 11-98) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER	U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR)
521.1001	To Be Assigned 09/831968

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/EP99/08799	November 16, 1999	November 20, 1998

TITLE OF INVENTION

SELF-RECOVERING CURRENT-LIMITING DEVICE WITH LIQUID METAL

APPLICANT(S) FOR DO/EO/US

Andreas KRAETZSCHMAR; Frank BERGER; Michael ANHEUSER; Wolfgang KREMERS

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ A copy of the International Search Report (PCT/ISA/210).
8. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☒ Certificate of Mailing by Express Mail
20. ☒ Other items or information:

- Letter re: Priority

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
09/831968 To Be Assigned	PCT/EP99/08799	521.1001

21. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

		CALCULATIONS PTO USE ONLY
☐	Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1,000.00**	
☒	International preliminary examination fee (37 CFR 1.482) not paid to USPTO but Internation Search Report prepared by the EPO or JPO **$860.00**	
☐	International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$710.00**	
☐	International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$690.00**	
☐	International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**	

ENTER APPROPRIATE BASIC FEE AMOUNT =	**$860.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	6 - 20 =	0	x $18.00	**$0.00**	
Independent claims	1 - 3 =	0	x $80.00	**$0.00**	
Multiple Dependent Claims **(check if applicable)**.			☐	**$0.00**	

TOTAL OF ABOVE CALCULATIONS =	**$860.00**	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable)**. ☐	**$0.00**	
SUBTOTAL =	**$860.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +	**$0.00**	
TOTAL NATIONAL FEE =	**$860.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☒	**$40.00**	
TOTAL FEES ENCLOSED =	**$900.00**	
	Amount to be: refunded	$
	charged	$

☒ A check in the amount of **$900.00** to cover the above fees is enclosed.

☐ Please charge my Deposit Account No. in the amount of to cover the above fees.
A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **50-0552** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

William C. Gehris, Esq.
Reg. No. 38,156
DAVIDSON, DAVIDSON & KAPPEL, LLC
485 Seventh Avenue
14th Floor
New York, New York 10018

23280
PATENT TRADEMARK OFFICE

SIGNATURE

William C. Gehris
NAME

38,156
REGISTRATION NUMBER

May 16, 2001
DATE

[521.1001]

UNITED STATES PATENT AND TRADEMARK OFFICE

Re: Application of:Andreas KRAETZSCHMAR et al.

Serial No.: To Be Assigned

International Application No.: PCT/EP99/08799

Filed: Herewith

For: SELF-RECOVERING CURRENT-LIMITING DEVICE WITH LIQUID METAL

BOX PCT
Asst. Commissioner for Patents
Washington, D.C. 20231

May 16, 2001

PRELIMINARY AMENDMENT

Sir:

Applicants request that the following Amendments be made in the above-identified matter prior to examination thereof:

IN THE SPECIFICATION

Before paragraph [0001], please change the heading "Field of the Invention" to --Field of the Invention--.

Please amend paragraph [0001] as follows:

[0001] The present invention relates to a self-recovering current-limiting device with liquid metal and including two electrodes made of solid metal.

Before paragraph [0002], please change the heading "Related Art" to --Related Technology--.

Please amend paragraph [0002] as follows:

[0002] Current-limiting devices with liquid metal are used for current limiting in low-voltage networks. Soviet Union Patent Document SU 922 911 A describes a self-recovering current-limiting device containing two electrodes which are made of solid metal and flatly configured toward the interior of the current-limiting device, the electrodes being separated by first insulating

bodies which are designed as a cylindrical, pressure-resistant insulating housing. Inside the insulating housing, compression spaces are formed by insulating intermediate walls and second insulating bodies which are arranged therebetween and designed as ring-shaped sealing disks, the compression spaces being partially filled with liquid metal and arranged one behind the other and interconnected via connecting channels of the intermediate walls, the connecting channels being filled with liquid metal and arranged off-center. Thus, in normal operation, a continuous, inner conductive connection exists between the electrodes via the liquid metal. In the current-limiting event, the liquid metal is abruptly displaced from the connecting channels as a result of the high current density. In this manner, the electrical connection of the electrodes via the liquid metal is interrupted, resulting in the limiting of the short-circuit current. Subsequent to clearing or eliminating the short-circuit, the connecting channels refill with liquid metal whereupon the current-limiting device is operational again. In German Patent Application DE 40 12 385 A1, vacuum, protective gas, or an insulating liquid are mentioned as the medium above the liquid level. According to Soviet Union Patent Document SU 1 076 981 A, the connecting channels of adjacent intermediate walls are staggered relative to each other for improving the limiting characteristics. It is known from German Patent Application DE 26 52 506 A1 to use gallium alloys, in particular gallium-indium-tin alloys (GaInSn alloys), in contact devices. It is a disadvantage that the known current-limiting devices function only in horizontal positions of use and in those slightly deviating therefrom. A known current-limiting device according to Soviet Union Patent Document SU 1 094 088 A is equipped with intermediate walls in which several connecting channels are formed in a circle around the center axis and with separating walls made of copper which are arranged between the intermediate walls and led outward for cooling the liquid metal. This current-limiting device permits positions of use involving rotations of up to 360° about the horizontal center axis and inclinations of up to 50° relative to the horizontal, which, however, is rendered possible only in conjunction with the separating walls, which disadvantageously carry a potential, the compression spaces having to be individually filled with liquid metal in a manner requiring too much effort because of these separating walls.

Before paragraph [0003], please change the heading "Summary of the Invention" to --Summary of the Invention--.

Please amend paragraph [0003] as follows:

[0003] Therefore, an object of the present invention is to provide a current-limiting device with liquid metal, the current-limiting device having an extended range of positions of use and being practical to manufacture and user-friendly.

After paragraph [0003], please insert paragraph [0003.1] as follows:

--[0003.1] The present invention provides aA self-recovering current-limiting device including a liquid metal, the device comprising:

a first and a second electrode for connection to an electric circuit to be protected, each of the first and second electrodes being made of solid metal, being rotationally symmetrical with respect to a longitudinal axis, and defining respective hollow spaces therein;

a plurality of pressure-resistant insulating bodies; and

a plurality of insulating intermediate walls interleaved with and supported by the plurality of pressure-resistant insulating bodies and defining a plurality of connecting channels disposed in a circular pattern, the plurality of pressure-resistant insulating bodies and the insulating intermediate walls together defining a plurality of compression spaces disposed between the first and second electrodes, the plurality of compression spaces being interconnected by the plurality of connecting channels and being at least partially filled with the liquid metal;

wherein the respective hollow spaces are each connected to an adjacent respective one of the plurality of compression spaces and wherein a respective volume of each of the hollow spaces and an amount of the liquid metal in the current-limiting device are selected so that an upper one of the first and second electrodes is sufficiently wetted with the liquid metal when the current-limiting device is in a position deviating substantially from a position when the longitudinal axis is horizontal.--.

Please delete paragraph [0004].

Please amend paragraph [0005] as follows:

[0005] The hollow spaces of the electrodes provide additional space serving as a reservoir for liquid metal which, when the position of use changes, is available at a different location, thus serving the sufficient reliability of the current-limiting device. In the horizontal position of use, that is, with the longitudinal axis of the current-limiting device being oriented horizontally, the filling of the hollow spaces and the wetting with liquid metal of the surfaces which are important for the current transfer are equal for both electrodes. When the longitudinal axis is inclined, the

hollow space of the electrode which moves upward empties of the liquid metal due to gravity in the measure in which the hollow space of the electrode which moves downward fills with liquid metal until, during further increasing inclination, the hollow space of the lower electrode fills completely with liquid metal and the hollow space of the upper electrode, in the extreme case, completely empties; however, this electrode still being sufficiently wetted with the liquid metal. A corresponding redistribution of the filling quantity takes place in the compression spaces, the plurality of connecting channels arranged per intermediate wall guaranteeing that in all intended positions of use, each intermediate wall is in contact with the liquid metal via at least one of its connecting channels. In each inclined position, in the case of an additional rotation about the longitudinal axis, the rotationally symmetrical design of the current-limiting device does not bring about any effective change in the distribution of the liquid metal in the hollow spaces and in the compression spaces so that during normal operation, a sufficient electrical connection between the electrodes exists in all possible positions of use. The connecting channels which are not in contact with the liquid metal serve, on one hand, for uniformly degassing the compression spaces during the filling of the current-limiting device and, on the other hand, for pressure compensation between adjacent compression spaces during and subsequent to a short-circuit event.

Please amend paragraph [0006] as follows:

[0006] The hollow spaces may have, for example, a pot-like, conically tapered design, or a double pot-like cylindrical design. In the latter case, a flat connecting lead can reach through the respective outer hollow space, the connecting lead taking the entire width of the outer hollow space for increasing the dimensional stability, a further opening serving the redistribution of the liquid metal in the outer hollow space during the inclination and rotation of the current-limiting device. A staggered arrangement of the connecting channels of adjacent intermediate walls prevents a long electric arc from burning across all compression spaces and, instead, forces the division into a plurality of effective, limiting partial electric arcs. GaInSn alloys as the liquid metal to be used are easy to handle because of their physiological harmlessness. An alloy of 660 parts by weight of gallium, 205 parts by weight of indium, and 135 parts by weight of tin is liquid from 10°C to 2000°C at normal pressure and possesses sufficient electrical conductivity.

Before paragraph [0007], please change the heading "Brief Description of the Drawings" to --Brief Description of the Drawings--.

Before paragraph [0014], please change the heading "Best Ways of Implementing the Present Invention" to --Detailed Description--.

Please amend paragraph [0014] as follows:

[0014] Current-limiting device 1 according to Fig. 1 and Fig. 2 contains one electrode 11 or 12 made of solid metal, preferably of copper, on each of the two sides, respectively, the electrode having a rotationally symmetrical design in relation to longitudinal axis 3 of current-limiting device 1 and merging into an outer connecting lead 13. Between electrodes 11 and 12, a plurality of compression spaces 4 are located which are formed by a corresponding number of ring-shaped sealing disks 5 made of insulating material and a corresponding number of insulating intermediate walls 6. Electrodes 11 and 12, sealing disks 5, and intermediate walls 6 are supported by an insulating housing 7, a known sealing device being provided for sealing compression spaces 4 and frictionally connecting elements 5, 6, 11, and 12, which are supported in insulating housing 7, however, the known sealing device not being shown for reasons of clarity. The sealing device can be, for example, sealing rings between sealing disks 5 and intermediate walls 6. The two outer compression spaces 4 are each laterally bounded by one of electrodes 11 and 12, respectively, and by an intermediate wall 6. Inner compression spaces 4 are each laterally bounded by two intermediate walls 6. Sealing disks 5 and the generally multi-part insulating housing 7 are pressure-resistant insulating bodies. All compression spaces 4 are at least partially filled with a liquid metal 8, for example, a GaInSn alloy. Located above liquid metal 8 is, for example, a vacuum. Intermediate walls 6 are provided with connecting channels 9. At least one connecting channel 9 of each intermediate wall 6 is filled with liquid metal 8 so that a continuous electrically conductive connection exists between electrodes 11 and 12. Intermediate walls 6 each have several connecting channels 9 which are arranged in a circle around center axis 3 and which, according to Fig. 5 and Fig. 6, are staggered by a certain angular value between adjacent intermediate walls 6 to prevent a continuous electric arc in the current-limiting event.

Page 8, first line change "What is claimed is" to --WHAT IS CLAIMED IS--.

IN THE CLAIMS:

Please cancel claims 1-6 as presented in the underlying International Application No. PCT/EP99/08799 and add new claims 7-12 as follows:

--7. (new) A self-recovering current-limiting device including a liquid metal, the device comprising:

a first and a second electrode for connection to an electric circuit to be protected, each of the first and second electrodes being made of solid metal, being rotationally symmetrical with respect to a longitudinal axis, and defining respective hollow spaces therein;

a plurality of pressure-resistant insulating bodies; and

a plurality of insulating intermediate walls interleaved with and supported by the plurality of pressure-resistant insulating bodies and defining a plurality of connecting channels disposed in a circular pattern, the plurality of pressure-resistant insulating bodies and the insulating intermediate walls together defining a plurality of compression spaces disposed between the first and second electrodes, the plurality of compression spaces being interconnected by the plurality of connecting channels and being at least partially filled with the liquid metal;

wherein the respective hollow spaces are each connected to an adjacent respective one of the plurality of compression spaces and wherein a respective volume of each of the hollow spaces and an amount of the liquid metal in the current-limiting device are selected so that an upper one of the first and second electrodes is sufficiently wetted with the liquid metal when the current-limiting device is in a position deviating substantially from a position when the longitudinal axis is horizontal.

8. (new) The device as recited in claim 7 wherein each of the hollow spaces have a pot-like shape tapering in a conical manner into an opening to the adjacent respective one of the plurality of compression spaces.

9. (new) The device as recited in claim 7 wherein each of the hollow spaces has a double pot-like shape and includes a respective cylindrical inner chamber and a respective cylindrical outer chamber, each of the first and second electrodes further defining a respective plurality of openings arranged in a circular pattern about the longitudinal axis for connecting the respective cylindrical outer chamber to the respective cylindrical inner chamber, each of the respective cylindrical inner chamber being connected to the adjacent respective one of the plurality of compression spaces.

Applicants believe that no fees are due as a result of this amendment. In the event of a fee discrepancy, please charge our Deposit Account No. 50-0552.

Respectfully submitted,

DAVIDSON, DAVIDSON & KAPPEL, LLC

By: ______________________

William C. Gehris (Reg. No. 38,156)
Davidson, Davidson & Kappel, LLC
485 Seventh Avenue - 14th Floor
New York, New York 10018
(212) 736-1940

"Express Mail" mailing label no.: EL 825522217 US
Date of deposit: May 16, 2001
I hereby certify that this correspondence and/or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above in an envelope addressed to "Commissioner of Patents and Trademarks, Washington, DC 20231"

DAVIDSON, DAVIDSON & KAPPEL, LLC
BY: ______________________
Samuel Gomez

openings arranged in a circular pattern about the longitudinal axis for connecting the respective cylindrical outer chamber to the respective cylindrical inner chamber, each of the respective cylindrical inner chamber being connected to the adjacent respective one of the plurality of compression spaces.

10. (new) The device as recited in claim 9 wherein each of the first and second electrodes includes a respective flat connecting lead dividing the respective outer chamber into two respective partial spaces, each respective flat connecting lead defining a respective opening for connecting the two respective partial spaces.

11. (new) The device as recited in claim 7 wherein respective ones of the plurality of connecting channels of adjacent intermediate walls are angularly staggered with respect to one another.

12. (new) The device as recited in claim 7 wherein the liquid metal includes a GaINSn alloy.--.

REMARKS

Consideration of this application, as amended, is respectfully requested.

Support for all new claims is found in the specification as originally filed. It is respectfully submitted that no new matter has been added.

conductive connection exists between the electrodes via the liquid metal. In the current-limiting event, the liquid metal is abruptly displaced from the connecting channels as a result of the high current density. In this manner, the electrical connection of the electrodes via the liquid metal is interrupted, resulting in the limiting of the short-circuit current. Subsequent to clearing or eliminating the short-circuit, the connecting channels refill with liquid metal whereupon the current-limiting device is operational again. In German Patent Application DE 40 12 385 A1, vacuum, protective gas, or an insulating liquid are mentioned as the medium above the liquid level. According to Soviet Union Patent Document SU 1 076 981 A, the connecting channels of adjacent intermediate walls are staggered relative to each other for improving the limiting characteristics. It is known from German Patent Application DE 26 52 506 A1 to use gallium alloys, in particular gallium-indium-tin alloys (GaInSn alloys), in contact devices. It is a disadvantage that the known current-limiting devices function only in horizontal positions of use and in those slightly deviating therefrom. A known current-limiting device according to Soviet Union Patent Document SU 1 094 088 A is equipped with intermediate walls in which several connecting channels are formed in a circle around the center axis and with separating walls made of copper which are arranged between the intermediate walls and led outward for cooling the liquid metal. This current-limiting device permits positions of use involving rotations of up to 360° about the horizontal center axis and inclinations of up to 50° relative to the horizontal, which, however, is rendered possible only in conjunction with the separating walls, which disadvantageously carry a potential, the compression spaces having to be individually filled with liquid metal in a manner requiring too much effort because of these separating walls.

Page 2, before paragraph [0003]: --Summary of the Invention--[Summary of the Invention]

Page 2, paragraph [0003]:

[0003] [The] Therefore, an object of the present invention is to [extend the] provide a current-limiting device with liquid metal, the current-limiting device having an extended range of positions of use [in a manufacturing] and being practical to manufacture and user-friendly [manner].

Page 2, paragraph [0005]:

[0005] The hollow spaces of the electrodes provide additional space serving as a reservoir for liquid metal which, when the position of use changes, is available at a different location, thus serving the sufficient reliability of the current-limiting device. In the horizontal position of use, that is, with the longitudinal axis of the current-limiting device being oriented horizontally, the filling of the hollow spaces and the wetting with liquid metal of the surfaces which are [decisive] important for the current transfer are equal for both electrodes. When the longitudinal axis is inclined, the hollow space of the electrode which moves upward empties [from] of the liquid metal due to gravity in the measure in which the hollow space of the electrode which moves downward fills with liquid metal until, during further increasing inclination, the hollow space of the lower electrode fills completely with liquid metal and the hollow space of the upper electrode, in the extreme case, completely empties; however, this electrode still being sufficiently wetted with the liquid metal. A corresponding redistribution of the filling quantity takes place in the compression spaces, the plurality of connecting channels arranged per intermediate wall guaranteeing that in all intended positions of use, each intermediate wall is in contact with the liquid metal via at least one of its connecting channels. In each inclined position, in the case of an additional rotation about the longitudinal axis, the rotationally symmetrical design of the current-limiting device does not bring about any effective change in the distribution of the liquid metal in the hollow spaces and in the compression spaces so that during normal operation, a sufficient electrical connection between the electrodes exists in all possible positions of use. The connecting channels which are not in contact with the liquid metal serve, on one hand, for uniformly degassing the compression spaces during the filling of the current-limiting device and, on the other hand, for pressure compensation between adjacent compression spaces during and subsequent to a short-circuit event.

Page 4, before paragraph [0014]: --Detailed Description--[Best Ways of Implementing the Present Invention]

Page 4, paragraph [0014]:

[0014] Current-limiting device 1 according to Fig. 1 and Fig. 2 contains one electrode 11 or 12 made of solid metal, preferably of copper, on each of the two sides, respectively, the electrode having a rotationally symmetrical design in relation to longitudinal axis 3 of current-limiting

device 1 and merging into an outer connecting lead 13. Between electrodes 11 and 12, a plurality of compression spaces 4 are located which are formed by a corresponding number of ring-shaped sealing disks 5 made of insulating material and a corresponding number of insulating intermediate walls 6. Electrodes 11 and 12, sealing disks 5, and intermediate walls 6 are supported by an insulating housing 7, [known means] a known sealing device being provided for sealing compression spaces 4 and frictionally connecting elements 5, 6, 11, and 12, which are supported in insulating housing 7, however, the known [means] sealing device not being shown for reasons of clarity. The [means for] sealing device can be, for example, sealing rings between sealing disks 5 and intermediate walls 6. The two outer compression spaces 4 are each laterally bounded by one of electrodes 11 and 12, respectively, and by an intermediate wall 6. Inner compression spaces 4 are each laterally bounded by two intermediate walls 6. Sealing disks 5 and the generally multi-part insulating housing 7 are pressure-resistant insulating bodies. All compression spaces 4 are at least partially filled with a liquid metal 8, for example, a GaInSn alloy. Located above liquid metal 8 is, for example, a vacuum. Intermediate walls 6 are provided with connecting channels 9. At least one connecting channel 9 of each intermediate wall 6 is filled with liquid metal 8 so that a continuous electrically conductive connection exists between electrodes 11 and 12. Intermediate walls 6 each have several connecting channels 9 which are arranged in a circle around center axis 3 and which, according to Fig. 5 and Fig. 6, are staggered by a certain angular value between adjacent intermediate walls 6 to prevent a continuous electric arc in the current-limiting event.

Page 8 first line : –WHAT IS CLAIMED IS--[What is claimed is]

SELF-RECOVERING CURRENT-LIMITING DEVICE WITH LIQUID METAL

Field of the Invention

[0001] The present invention relates to a self-recovering current-limiting device with liquid metal according to the definition of the species in Claim 1. Current-limiting devices of that kind are used for current limiting in low-voltage networks.

Related Art

[0002] Soviet Union Patent Document SU 922 911 A describes a self-recovering current-limiting device containing two electrodes which are made of solid metal and flatly configured toward the interior of the current-limiting device, the electrodes being separated by first insulating bodies which are designed as a cylindrical, pressure-resistant insulating housing. Inside the insulating housing, compression spaces are formed by insulating intermediate walls and second insulating bodies which are arranged therebetween and designed as ring-shaped sealing disks, the compression spaces being partially filled with liquid metal and arranged one behind the other and interconnected via connecting channels of the intermediate walls, the connecting channels being filled with liquid metal and arranged off-center. Thus, in normal operation, a continuous, inner conductive connection exists between the electrodes via the liquid metal. In the current-limiting event, the liquid metal is abruptly displaced from the connecting channels as a result of the high current density. In this manner, the electrical connection of the electrodes via the liquid metal is interrupted, resulting in the limiting of the short-circuit current. Subsequent to clearing or eliminating the short-circuit, the connecting channels refill with liquid metal whereupon the current-limiting device is operational again. In German Patent Application DE 40 12 385 A1, vacuum, protective gas, or an insulating liquid are mentioned as the medium above the liquid level. According to Soviet Union Patent Document SU 1 076 981 A, the connecting channels of adjacent intermediate walls are staggered relative to each other for improving the limiting characteristics. It is known from German Patent Application DE 26 52 506 A1 to use gallium alloys, in particular gallium-indium-tin alloys (GaInSn alloys), in contact devices. It is a disadvantage that the known current-limiting devices function only in horizontal

positions of use and in those slightly deviating therefrom. A known current-limiting device according to Soviet Union Patent Document SU 1 094 088 A is equipped with intermediate walls in which several connecting channels are formed in a circle around the center axis and with separating walls made of copper which are arranged between the intermediate walls and led outward for cooling the liquid metal. This current-limiting device permits positions of use involving rotations of up to 360° about the horizontal center axis and inclinations of up to 50° relative to the horizontal, which, however, is rendered possible only in conjunction with the separating walls, which disadvantageously carry a potential, the compression spaces having to be individually filled with liquid metal in a manner requiring too much effort because of these separating walls.

Summary of the Invention

[0003] Therefore, the object of the present invention is to extend the range of positions of use in a manufacturing- and user-friendly manner.

[0004] On the basis of a current-limiting device of the type mentioned at the outset, this objective is achieved according to the present invention by the characterizing features of the independent claim whereas advantageous refinements of the present invention can be gathered from the dependent claims.

[0005] The hollow spaces of the electrodes provide additional space serving as a reservoir for liquid metal which, when the position of use changes, is available at a different location, thus serving the sufficient reliability of the current-limiting device. In the horizontal position of use, that is, with the longitudinal axis of the current-limiting device being oriented horizontally, the filling of the hollow spaces and the wetting with liquid metal of the surfaces which are decisive for the current transfer are equal for both electrodes. When the longitudinal axis is inclined, the hollow space of the electrode which moves upward empties from the liquid metal due to gravity in the measure in which the hollow space of the electrode which moves downward fills with

liquid metal until, during further increasing inclination, the hollow space of the lower electrode fills completely with liquid metal and the hollow space of the upper electrode, in the extreme case, completely empties; however, this electrode still being sufficiently wetted with the liquid metal. A corresponding redistribution of the filling quantity takes place in the compression spaces, the plurality of connecting channels arranged per intermediate wall guaranteeing that in all intended positions of use, each intermediate wall is in contact with the liquid metal via at least one of its connecting channels. In each inclined position, in the case of an additional rotation about the longitudinal axis, the rotationally symmetrical design of the current-limiting device does not bring about any effective change in the distribution of the liquid metal in the hollow spaces and in the compression spaces so that during normal operation, a sufficient electrical connection between the electrodes exists in all possible positions of use. The connecting channels which are not in contact with the liquid metal serve, on one hand, for uniformly degassing the compression spaces during the filling of the current-limiting device and, on the other hand, for pressure compensation between adjacent compression spaces during and subsequent to a short-circuit event.

[0006] Advantageous embodiments of the hollow spaces are, first of all, a pot-like, conically tapered design and, secondly, a double pot-like cylindrical design. In the latter case, a flat connecting lead can reach through the respective outer hollow space, the connecting lead taking the entire width of the outer hollow space for increasing the dimensional stability, a further opening serving the redistribution of the liquid metal in the outer hollow space during the inclination and rotation of the current-limiting device. A staggered arrangement of the connecting channels of adjacent intermediate walls prevents a long electric arc from burning across all compression spaces and, instead, forces the division into a plurality of effective, limiting partial electric arcs. GaInSn alloys as the liquid metal to be used are easy to handle because of their physiological harmlessness. An alloy of 660 parts by weight of gallium, 205 parts by weight of indium, and 135 parts by weight of tin is liquid from 10°C to 2000°C at normal pressure and possesses sufficient electrical conductivity.

Brief Description of the Drawings

[0007] Further details and advantages of the present invention ensue from the following exemplary embodiments which will be explained on the basis of Figures.

[0008] Figure 1 shows a longitudinal section of a first exemplary embodiment of the current-limiting device according to the present invention in a horizontal position.

[0009] Figure 2 shows the current-limiting device according to Figure 1 in a vertical position.

[0010] Figure 3 shows a longitudinal section of a second exemplary embodiment of the current-limiting device according to the present invention in a horizontal position.

[0011] Figure 4 shows the current-limiting device according to Figure 3 in a vertical position.

[0012] Figure 5 shows the current-limiting device according to Fig. 1 or Fig. 3 in cross-section A-A.

[0013] Figure 6 shows the current-limiting device according to Fig. 1 or Fig. 3 in cross-section B-B.

Best Ways of Implementing the Present Invention

[0014] Current-limiting device 1 according to Fig. 1 and Fig. 2 contains one electrode 11 or 12 made of solid metal, preferably of copper, on each of the two sides, respectively, the electrode having a rotationally symmetrical design in relation to longitudinal axis 3 of current-limiting device 1 and merging into an outer connecting lead 13. Between electrodes 11 and 12, a plurality of compression spaces 4 are located which are formed by a corresponding number of ring-shaped sealing disks 5 made of insulating material and a corresponding number of insulating intermediate walls 6. Electrodes 11 and 12, sealing disks 5, and intermediate walls 6 are supported by an insulating housing 7, known means being provided for sealing compression spaces 4 and frictionally connecting elements 5, 6, 11, and 12, which are supported in

insulating housing 7, however, the known means not being shown for reasons of clarity. The means for sealing can be, for example, sealing rings between sealing disks 5 and intermediate walls 6. The two outer compression spaces 4 are each laterally bounded by one of electrodes 11 and 12, respectively, and by an intermediate wall 6. Inner compression spaces 4 are each laterally bounded by two intermediate walls 6. Sealing disks 5 and the generally multi-part insulating housing 7 are pressure-resistant insulating bodies. All compression spaces 4 are at least partially filled with a liquid metal 8, for example, a GaInSn alloy. Located above liquid metal 8 is, for example, a vacuum. Intermediate walls 6 are provided with connecting channels 9. At least one connecting channel 9 of each intermediate wall 6 is filled with liquid metal 8 so that a continuous electrically conductive connection exists between electrodes 11 and 12. Intermediate walls 6 each have several connecting channels 9 which are arranged in a circle around center axis 3 and which, according to Fig. 5 and Fig. 6, are staggered by a certain angular value between adjacent intermediate walls 6 to prevent a continuous electric arc in the current-limiting event.

[0015] According to the present invention, electrodes 11 and 12 are provided with a pot-like hollow space 14 which, in each case, is connected to adjacent compression space 4 in a conically tapering manner via an opening 16. Via openings 16 and via connecting channels 9, liquid metal 8 is distributed over hollow spaces 14 of electrodes 11, 12 and over compression spaces 4, depending on the position of use of current-limiting device 1. In this connection, hollow spaces 14 are more or less filled with liquid metal 8. In the horizontal position of current-limiting device 1 depicted in Fig. 1, liquid metal 8 is uniformly distributed both over the two hollow spaces 14 of electrodes 11 and 12 and over all compression spaces 4. In this position, both a large part of the inner surface of hollow space 14 and the surface bordering adjacent compression space 4 are wetted with liquid metal 8 in each electrode 11 and 12. In this position, moreover, the largest part of connecting channels 9 are below liquid level 81 while the remaining part is above it. In the vertical position of current-limiting device 1 which is depicted in Fig. 2 and which extremely deviates from the

horizontal position, hollow space 14 of electrode 11, which has moved downward, has completely filled with liquid metal 8 whereas hollow space 14 of electrode 12, which has moved upward, has emptied from liquid metal 8 for the most part, however, a sufficient part of the surface of upper electrode 12, namely, in its entirety, the surface bordering adjacent compression space 4 and opening 16 still being wetted with liquid metal 8. Moreover, all connecting channels 9 of all intermediate walls 6 are below liquid level 82 which runs in the region of opening 16 of upper electrode 12.

[0016] Current-limiting device 2 depicted in Fig. 3 and Fig. 4 differs from previously described current-limiting device 1 in the design of electrodes 21 and 22. According to the present invention, electrodes 21 and 22 have a double pot-like design. Each of them possesses a cylindrical inner hollow space 25 which is open toward adjoining compression space 4, and a cylindrical outer hollow space 24 which is separated from the inner hollow space by a dividing wall 27. Outer hollow space 24 communicates with adjacent inner hollow space 25 via several openings 26 which are arranged in dividing wall 27 in a circle around center axis 3. A flat connecting lead 23 extends from dividing wall 27 of each electrode 21 and 22, respectively, the connecting lead dividing outer hollow space 24 into two partial spaces 241 and 242 which are connected via at least one further opening 28 in connecting lead 23. Via openings 26, 28 and via connecting channels 9, liquid metal 8 is distributed over hollow spaces 24, 25 of electrodes 21, 22 and over compression spaces 4, depending on the position of use of current-limiting device 2. In the horizontal position of current-limiting device 2 depicted in Fig. 3, liquid metal 8 is in each case uniformly distributed over outer hollow spaces 24 and inner hollow spaces 25 of both electrodes 21 and 22 and uniformly over all compression spaces 4. In this position, a large part of the inner surfaces of hollow spaces 24 and 25 is wetted with liquid metal 8 in each electrode 21 and 22. In this position, moreover, the largest part of connecting channels 9, which are arranged in a circle, are below liquid level 83 while the remaining part is above it. In the vertical position of current-limiting device 2 which is depicted in Fig. 4 and which extremely deviates from the horizontal position, hollow spaces 24 and 25 of

electrode 21, which has moved downward, have completely filled with liquid metal 8 whereas outer hollow space 24 of electrode 22, which has moved upward, has completely emptied from liquid metal 8, however, the complete filling of inner hollow space 25 providing that upper electrode 22 is sufficiently wetted with liquid metal 8. Moreover, all connecting channels 9 of all intermediate walls 6 are below liquid level 84 which runs in the region of openings 26 of upper electrode 22.

[0017] The present invention is not limited to the above-described specific embodiments but also includes all equally acting embodiments along the lines of the present invention. Thus, for example, the knowledge of the internal pressure of the medium located above the liquid metal represents meaningful information on the functional reliability of the current-limiting device. This can advantageously be achieved by a pressure measuring device which reaches into the interior of the current-limiting device and which can be read from outside, for example, by a diaphragm pressure gauge which derives its reading from the pressure energy that is present inside, or by a gas friction vacuum gauge which, via a corresponding measuring head and a display unit, can indicate the pressure on request. Moreover, for regular monitoring of the current-limiting device it is advantageous if quality-deteriorating changes of the liquid metal, for example, due to contaminating or wearing thermal and/or chemical decomposition products or impurities, can be checked via a diagnostic opening which reaches into the interior of the current-limiting device, for example, for a corresponding diagnostic probe or a suction sampling device.

What is claimed is:

1. A self-recovering current-limiting device with liquid metal containing two electrodes (11, 12; 21, 22) made of solid metal which are rotationally symmetrical in relation to the longitudinal axis (3) of the current-limiting device (1; 2) and which are used for the connection to an electric circuit to be protected, and containing a plurality of compression spaces (4) which are partially filled with liquid metal (8) and arranged one behind the other between the electrodes (11, 12; 21, 22) and which are formed by pressure-resistant insulating bodies (5, 7) and insulating intermediate walls (6) which are supported by the insulating bodies and which have several connecting channels (9) which are distributed in a circle,
wherein the electrodes (11, 12; 21, 22) have hollow spaces (14; 24, 25) which are connected to the adjacent compression spaces (4) and whose volume as well as the filling quantity of the liquid metal (8) are selected such that in the position of use of the current-limiting device (1; 2) which extremely deviates from the horizontal position of use, the upper of the two electrodes (11, 12; 21, 22) is still sufficiently wetted with the liquid metal (8).

2. The current-limiting device as recited in Claim 1,
wherein the electrodes (11; 12) are each designed to include a pot-like hollow space (14) which merges into an opening (16) to the adjacent compression space (4) in a conically narrowed manner.

3. The current-limiting device as recited in Claim 1,
wherein the electrodes (21, 22) have a double pot-like design having an essentially cylindrical inner hollow space (25) and a similar outer hollow space (24) which, via concentrically arranged openings (26), is connected to the inner hollow space (25) which is open toward the adjacent compression space (4).

4. The current-limiting device as recited in Claim 3,

wherein the electrodes (21, 22) are designed to include a flat connecting lead (23) which divides the respective outer hollow space (24) into two partial spaces (241, 242) and which connects the two partial spaces (241, 242) via at least one further opening (28).

5. The current-limiting device as recited in one of the preceding Claims, wherein the connecting channels (9) of adjacent intermediate walls (6) are in each case angularly staggered.

6. The current-limiting device as recited in one of the preceding Claims, wherein the liquid metal (8) is a GaInSn alloy.

Abstract

The invention relates to a self-recovering current-limiting device with liquid metal. The device contains two solid metal electrodes (11, 12) which are rotationally symmetrical in relation to the longitudinal axis (3) of th current limiting device (1) and several compression chambers (4) which are partially filled with liquid metal (8) and arranged in a series between the electrodes (11, 12). The compression chambers are formed by pressure-resistant insulating bodies (5, 7) and insulating intermediate walls (6) which are supported by the same (6) and which have several connecting channels (9), distributed in a circular form. The aim of the invention is to extend the positions of use. To ths end, the electrodes (11, 12) have cavities (14) which are connected to the adjacent compression chambers (4) by openings (16) and which are adequately wetted to completely filled with the liquid metal (8), according to the position of use.

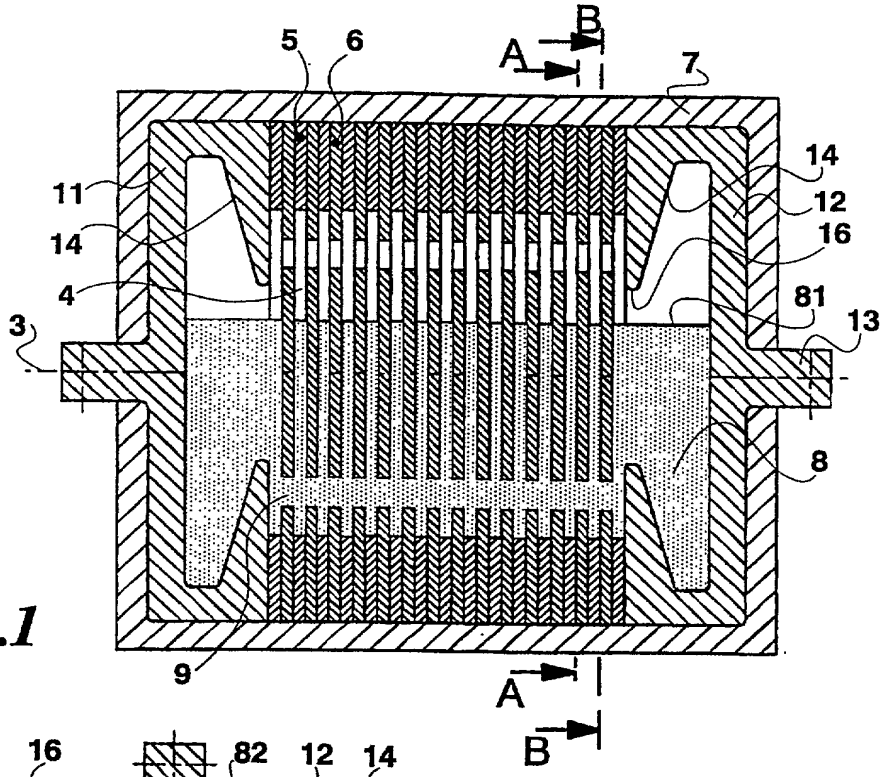


Fig.1

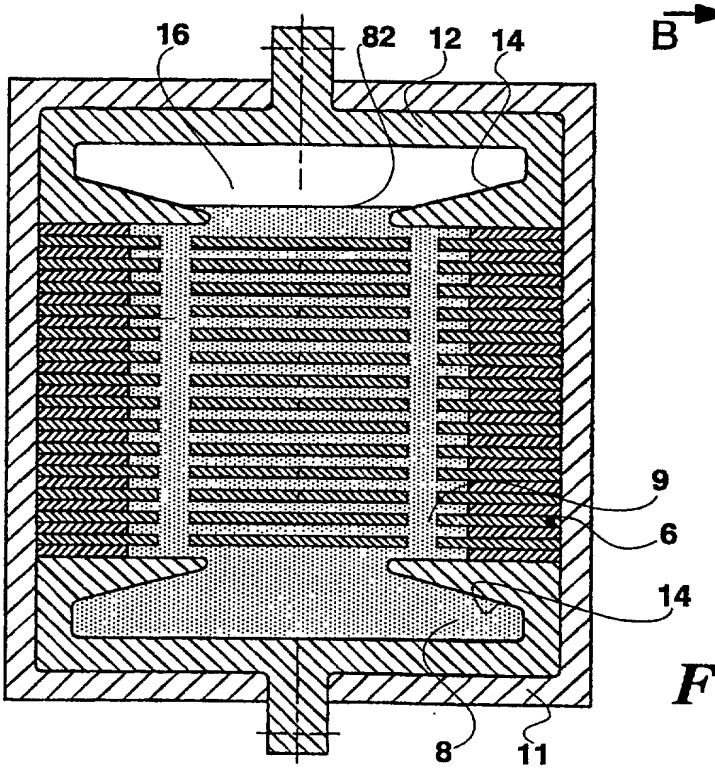
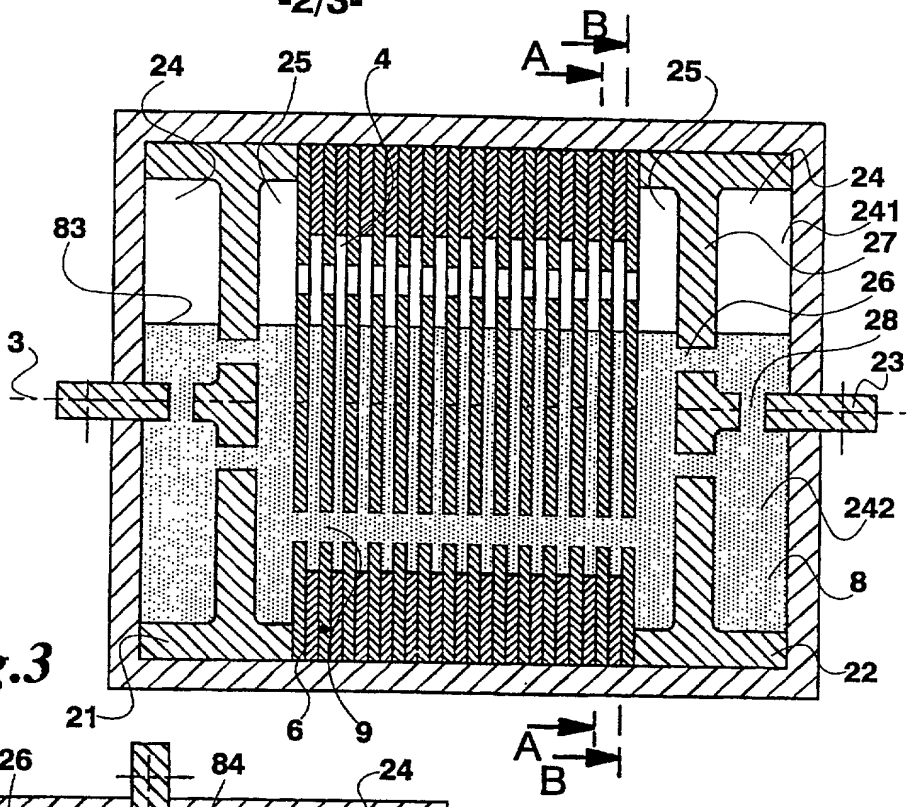


Fig.2


B
A
24
25
4
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241
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23
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3
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8
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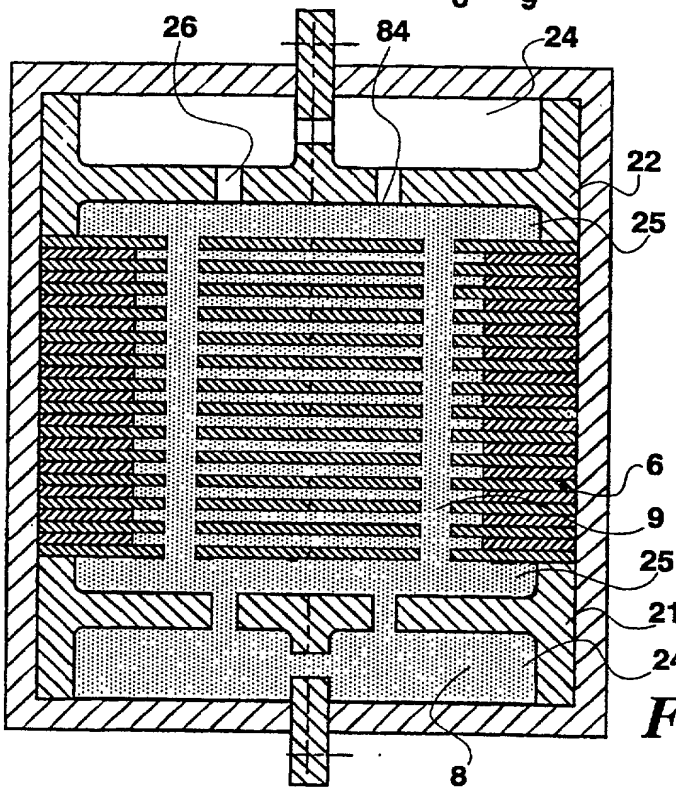
21
6
9
A
B

Fig.3


26
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22
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24
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2

Fig.4

A-A

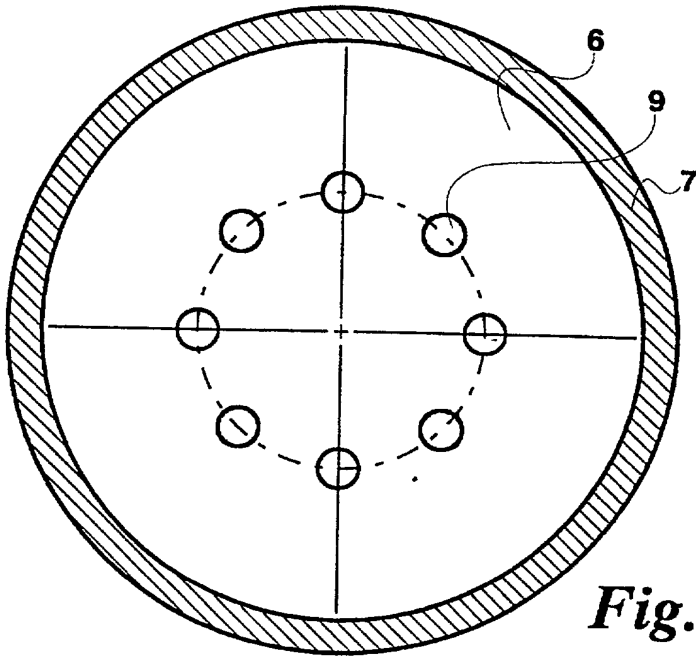

Fig.5

B-B

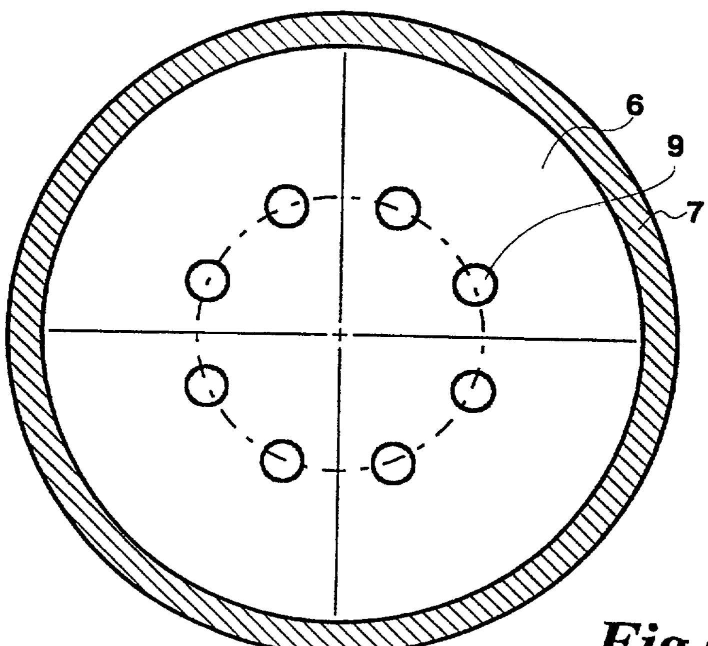

Fig.6

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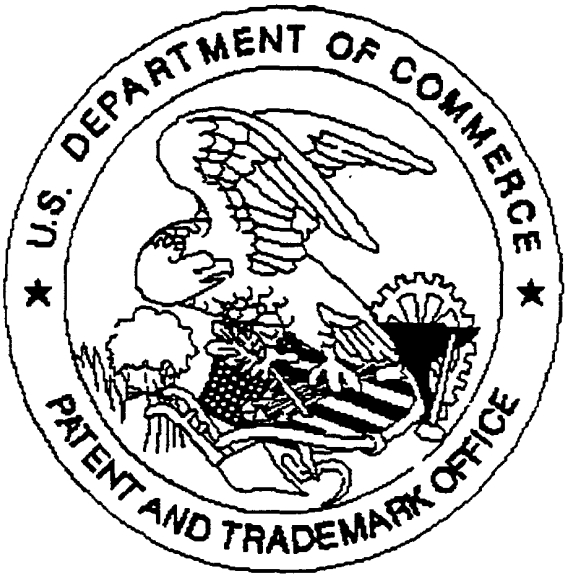

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